Mitsuo SUZUKI* & Kiyotsugu YODA**: **Comparative wood anatomy of *Coriaria* of East Asia** (1)***

鈴木三男*・依田清胤**: 東亜産ドクウツギ属木材の比較解剖 (1)

(Pl. IV–VII)

Coriaria is a well-known genus because of the isolation in the distribution in the world. According to Good (1930), about 20 species are distributed in four isolated regions in the world: one species is in Mediterranean, seven species are in East Asia, or from Japan to Himalaya, six species are from New Zealand to Papua New Guinea through Samoa, Fiji and New Hebrides, and four species are from north Mexico to southern Chile through tropical America and Andes. For interpreting the isolation in distribution, Maekawa (1960a, 1960b, 1963) offered a trans-palaeo-equatorial distribution theory. In this theory, he said the genus *Coriaria*, one of the archaetypic angiosperms, originated in tropical montaine regions along the palaeo-equator in the Mesozoic Era, and still now they were living there as the evidence of the remnant scar of its aboriginal distributional range. Soon after him, Melville (1966) tried to interpret the distribution of *Coriaria* as the result of continental drift of Gondwanaland where *Coriaria* originated and the succeeding migration after the continental drift.

Coriaria is a quite distinct genus and constitutes the monogeneric family, Coriariaceae. Its reproductive organ is regarded by many students as one of the ancient or primitive type, but its direct affinity in the dicotyledons is rather obscure. This family is often put into the Sapindales by many taxonomists (Engler 1964, Lawrence 1970 and others). Sharma (1968) studied on floral morphology and embryology of a Himalayan *Coriaria*, *C. napalensis*, and concluded that Coriariaceae perhaps represents an isolated ancient stock having a remote connection with some of the arborescent families included in Sapindales. Garg

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(1980) studied *C. napalensis* palynologically and also suggested close affinity with Sapindaceae. There are, however, other opinions concerning the affinity of this family, and it may be said that there is no positive evidence to indicate the affinity with any families in Sapindales or also in any other orders (cf. Good 1930, Carlquist 1985). On the other hand, wood anatomical studies are sometimes available to clarify not only the intrafamilial but also interfamilial affinities. Recently, Carlquist (1985) carried on a wood anatomical research on four species of *Coriaria*, three Southern Hemisphere species and one Japanese species. Although he suggested some resemblances of wood structure in these species to the selected genera of Ranunculaceae, Corynocarpaceae and Simaroubaceae, he recommended the necessity of an extensive research for elucidation of the affinities of Coriariaceae.

Independently of the study of Carlquist, we have been performing a study on comparative wood anatomy of *Coriaria* for elucidating whether it is surely primitive and regarded surely as aborigines of the trans-palaeo-equatorial areas as suggested by Maekawa or not. In our study, we used four East Asian species, *C. terminalis* Hems., *C. japonica* A. Gray, *C. napalensis* Wall. and *C. intermedia* Matsum. According to Good (1930), there are two groups of *Coriaria* in East Asia, i.e., A-group with large terminal and solitary racemes with only one representative, *C. terminalis*, and B-group, in which *C. japonica*, *C. napalensis*, *C. intermedia* and several other species are included, with short, generally clustered, lateral and axillary racemes. In this paper we try to clarify the degree of advancement of these species in the wood structure and also the phylogenetic relationship among the East Asian species.

Japanese species, *C. japonica*, is a poisonous and deciduous shrub with terrestrial stems 1-2 m high and several centimeters thick. It usually grows in sunny open places such as volcano, dried river floor with sand and gravels, road side, and some other places. Its shoots sprout in the spring, flower in the next spring, and, after the fruit maturation, usually die down before the second winter. Therefore, the secondary wood accumulation is very meager and the wood has not any commercial use. On the other hand, one of the Himalayan species, *C. napalensis*, is a deciduous tree with a trunk 2-8 m high and 10-45 cm thick. It grows in open land or in secondary forests as pioneer trees, but the wood of this species has been scarcely studied. The other Himalayan *Coriaria*, *C. terminalis*, is a small shrub or herb about 1 m in height.

Its terrestrial shoots sprout in the spring, terminate inflorescences, and, after fructification, die down in the autumn. Therefore, there is no accumulation of secondary wood except the subterranean stem. The Formosan species, *C. intermedia*, is also a small tree like *C. napalensis*.

Materials and methods Specimens investigated in this paper are listed in Tab. 1 with their ecological data. Wood specimens of Japanese species, *C. japonica*, were collected from three individuals: one specimen from a terrestrial shoot of a plant (No. 9064), three specimens from three different parts of another plant, that is, a part of an aerial shoot (No. 9249), a basal part of the shoot (No. 9247) and a part of an underground stump (No. 9245), and two specimens from the third plant, i.e., a specimen from basal part of an terrestrial shoot (No. 9260) and another specimen from the underground stem (No. 9263). Seven wood specimens of *C. napalensis* (Nos. 8340004, 8340213, 8340287, 8340390, 8540009, 8540010 and 8540016) were collected from six plants in central to eastern Nepal on the course of the expedition "a taxonomic research on the plants diversified in the eastern Himalaya" organized by the University of Tokyo in 1983 and 1985. No. 8540010 was obtained from a 5-year-old shoot of the plant from which No. 8540009 was cut off. The wood specimen of *C. intermedia* was kindly collected from Taiwan by Mr. Noshiro et al. This wood specimen was collected as small cubic blocks (about 2×2×2 cm) using hammer and chisel from an erect tree. It is the oldest part of the plant but the age of the plant is unknown. Wood specimen was killed by and stored in dilute formaldehyde solution. A specimen of *C. terminalis* was obtained from a herbarium specimen (TI No. 12316) deposited in the herbarium of the University of Tokyo. The specimen was cut from the subterranean stem.

After softening by boiling in water, the specimens were cut by sliding microtome at a thickness of 20-30 μm. The thin sections are stained by safranin O and fastgreen FCF and observed by the light microscope. On the other hand, some of the remaining blocks of specimens after cutting were dried and observed under the scanning electron microscope to observe the intervessel pits. Important quantitative characteristics of the examined wood specimens are listed in Tab. 2 and 3.

All of the voucher specimens are deposited in the herbarium of the University of Tokyo, and the microscopic preparations are in Department of Biology, College of Liberal Arts, Kanazawa University, and the herbarium of the Uni-

Tab. 1. List of investigated *Coriaria* specimens.

Specimen Number	Plant Number	Locality	Altitude (m)	Collector	Height (m)	Diameter 1) (cm)	Age 2) (year)
C. japonica							
9064	japo-1	Ozo River, Oguchi, Ishikawa pref.	400	Suzuki & Yoda	ca 1.2	1.4	1
9245	japo-2	Tedori River, Tatsunokuchi, Ishikawa pref.	80	Yoda	ca 1.0	3.2	3
9247	japo-2	Tedori River, Tatsunokuchi, Ishikawa pref.	80	Yoda	ca 1.0	2.0	3
9249	japo-2	Tedori River, Tatsunokuchi, Ishikawa pref.	80	Yoda	ca 1.0	1.8	3
9263	japo-3	Tedori River, Tatsunokuchi, Ishikawa pref.	80	Yoda	ca 2.0	8.5	4
9264	japo-3	Tedori River, Tatsunokuchi, Ishikawa pref.	80	Yoda	ca 2.0	4.0	3
C. napalensis							
8340004	nepa-1	Nagarjun Ban, Kathmandu, Nepal	1390	Ohba et al.	—	15.0	—
8340213	nepa-2	Kalopani-Tukche, Kali Gandaki, Nepal	2480	Ohba et al.	8.0	45.0	—
8340287	nepa-3	Bratang-Chame, Marsyandi Khora Nepal	2850	Ohba et al.	7.0	25.0	—
8340390	nepa-4	Bahundanda-Baragaon, Marsyandi Khora, Nepal	1100	Ohba et al.	2.0	10.0	—
8540009	nepa-5	Munga, Langtan, Nepal	2050	Suzuki & Noshiro	5.0	20.0	—
8540010	nepa-5	Munga, Langtan, Nepal	2050	Suzuki & Noshiro	5.0	3.5	5
8540016	nepa-6	Munga-Syabru, Langtan, Nepal	2170	Suzuki & Noshiro	5.0	25.0	—
C. intermedia							
9322	inte-1	Tataga-Paiyun Sunjuan, Mt. Yushan, Taiwan	2740	Minaki et al.	2.0	10.0	—
C. terminalis							
12316	term-1	Chamsa (3500 m)-Kohina (3000 m)-Yabu Thang (3200 m), Bhutan	—	Kanai et al.	ca 1.0	1.3	3

1) Diameter of investigated part. 2) Age of investigated part.

versity of Tokyo.

Description

Coriaria japonica (Pl. IV, figs. 1-4)

Wood is diffuse at one- or two-year-old parts but shows a distinct tendency to be a semi-ring porous in the third annual rings. Growth rings are indistinct in the younger parts and more distinct in the older parts.

Pores are evenly distributed and few to many (29–114 pores per square mm in average), mostly in multiple (2–5 or more pores in a multiple) and sometimes solitary, medium-sized in the early wood (47.5-104.7 and 87.7-149.6 μm in average tangential and radial diameter respectively), and a little smaller in the late wood (44.5-56.0 and 37.6-114.6 μm in average tangential and radial diameters respectively), oval or polygonal in outline with thin walls. Vessel elements are short (114.1-182.6 μm in average length). Perforation plates are exclusively simple. Intervessel pits are sparse or more or less dense (15-18 pits per 625 square μm in average), arranged in alternate, oval or horizontally long elliptical in outline with 5-10 μm in diameter. Vestured pits are invisible by light microscope. Spiral thickenings are invisible.

Non-perforated tracheal elements are libriform fibers which constitute the ground mass of the wood, polygonal in outline with rather thick walls, fairly short with very small pits.

Wood parenchyma is less abundant, vasicentric and confluent, rectangular to polygonal in outline, fusiform or strands with two or rarely four cells; crystals invisible.

Rays are heterogeneous and large, rather narrow (2-12-celled), very high (often exceed the height of the thin sections). Ray occupation ratio is 32.4-43.0% (which means the ray portion of total horizontal length measured in tangential section). Ray cells are upright, square or procumbent, and variable in size. Crystals are sometimes present but not abundant.

Small vessels and wood parenchyma show weak tendency to be storied structure, and sometimes they show fairly distinct storied structure. Rays are not storied.

Coriaria napalensis (Pl. V, figs. 5-8; Pl. VI, figs. 12-13; Pl. VII, figs. 17-18)

Wood is semi-ring porous. At the beginning of annual rings, clusters of large pores are arranged in one concentric series. Annual rings are fairly distinct or sometimes indistinct. Pores are often arranged in tangential direction showing distinct tangential bands with confluent parenchyma, rather few (21-86 pores in a square mm in averrge), mostly grouped in clusters with several pores (2-20, mostly 2-6 pores in a multiple) and rarely solitary, mostly polygonal in outline with rather thin walls, moderately large in the early wood (149.6-165.3 and 156.9-190.3 μm in average tangential and radial diameters respectively) and a little smaller in the late wood (49.3-85.5 and 54.1-91.7 μm in average tangential and radial diameters respectively). Vessel elements are short (117.1-220.0 μm in average length). Perforation plates are exclusively simple. Inter-vessel pits are densely distributed (17-25 pits per 625 square μm in average), polygonal in outline with about 5-6 μm in diameter and arranged in alternate; vestured pits invisible by the light microscope and also by scanning electron microscope (figs. 17-18). Spiral thickenings are invisible.

Non-perforated tracheal elements are libriform fibers which constitute the ground mass of the wood, polygonal in outline with rather thick walls, fairly short and show a little tendency to be in storied with other elements; very small pits with slit-like apertures often present.

Wood parenchyma are rather abundant, vasicentric and confluent, polygonal in outline with thin walls, mostly fusiform and sometimes strands with two or four cells; crystals invisible.

Rays are heterogeneous and sheathed, very large and variable in size, 3-24-celled or 50-480 μm in width, very high and often exceed the height of the thin section. Ray occupation ratio is 32.7-45.4%. Rays consist of three kinds of cells which are variable in shape and size and thin-walled, that is, very high and short uprignt cells, square cells and slightly long procumbent cells. The upright cells are disposed around the central cores of the square and procumbent cells as sheath cells, and their height often reaches to that of the storied elements, or the vessel elements and fusiform parenchyma. Therefore, it is sometimes difficult to distinguish the upright cells from the fusiform wood parenchyma in tangential section. Crystals are often present in the square cells.

Small vessels and wood parenchyma constitute a quite evident storied structure. Rays are not storied.

Coriaria intermedia (Pl. VI, figs. 9-11)

The wood structure of this species is very similar to that of *C. napalensis*. Therefore, only different points and quantitative characters will be described.

Wood is semi-ring porous with distinct annual rings. Pores are rather few (28 pores per square mm in early wood and 42 pores in the late wood in average). Pores are in tangential clusters with 2–13 pores or sometimes solitary. Pores are medium-sized in the early wood (110.7 and 124.8 μm in tangential and radial average diameters respectively), and small in the late wood (47.9 and 56.3 μm in tangential and radial average diameters respectively). Vessel elements are short (145.0 μm in average length). Intervessel pits are rather sparse than in *C. napalensis*, polygonal to oval in outline.

Rays are wide (10–14-celled and 170–250 μm in width) ; rather low (0.2–3.97 mm in height). Ray occupation ratio is 42.1%. Crystals invisible.

Small vessels and wood parenchyma are distinctly storied, but rays show any tendency to be storied.

Coriaria terminalis (Pl. VII, figs. 14–16)

The wood structure of this species is also similar to other three species. Therefore, only different points from those of other three species and quantitative characters are described here.

Just like as *C. japonica*, wood is diffuse in one-year-old part but semi-ring porous in 2- and 3-year-old part. Growth rings are distinct. Pores are rather few (45 and 54 pores per square mm), usually in multiple of radial or oblique (2–6 pores in a multiple), and rarely solitary. Pores are a little smaller in the early wood (84.5 and 100.6 μm in tangential and radial average diameters respectively), and small in the late wood (48.1 and 52.8 μm in tangential and radial average diameters respectively). Vessel elements are short (133.1 μm in average length). Intervessel pits are very dense (33 pits per 625 square μm), polygonal in outline with about 5 μm in diameter, alternately arranged. Wood parenchyma are rather fewer.

Rays are wide (8–17-celled and 180–350 μm in width) and fairly high. Ray occupation ratio is 40.8%. Crystals are abundant in the square cells.

Small vessels and wood parenchyma show a little tendency to be storied.

(To be continued)

Explanation of Plates IV–VII

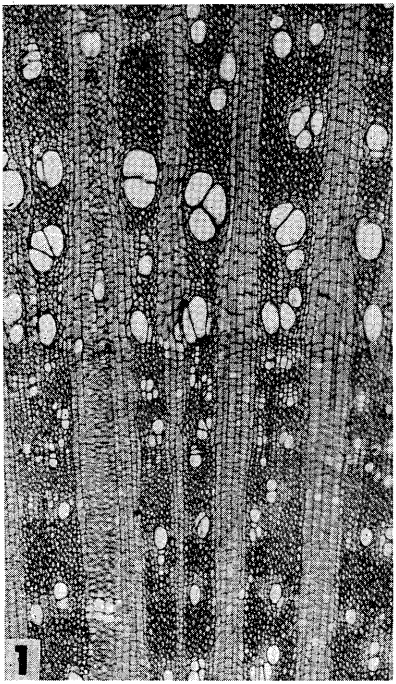
Plate IV. *Coriaria japonica* 1: A cross section of a three-year-old stem (No. 9245) showing a boundary of the growth rings and pore distribution between the late wood pores in the second growth ring and a litte larger early

wood pores in the beginning of the third growth ring (×40). Pores are mostly in multiple and show a tendency to be a ring porous structure. 2: A cross section of one-year-old stem (No. 9064) with diffused pore distribution (×40). 3: A more magnified cross section (No. 9245) showing solitary early wood large pores, small late wood pores in multiple, confluent wood parenchyma and wide rays (×100). 4: A tangential section (No. 9245) showing broad and very high rays, and fairly developed storied structure at the left above (×40).

Plate V. *Coriaria napalensis* (No. 8340390). 5: A cross section showing semi-ring porous structure in the three growth rings and pores mostly in multiple and sometimes solitary (×40). 6: A more magnified cross section showing a growth ring boundary, large early wood pores and multiple small late wood pores with abundant confluent wood parenchyma (×100). 7: A tangential section showing broad and very high rays and storied arrangement of small vessels, wood fibers and wood parenchyma (×40). Sheath cells are fairly larger than cells at the central core of the rays. 8: A more magnified tangential section showing beautifully storied small vessels, fusiform parenchyma and two-celled parenchyma strands (×100).

Plate VI. *Coriaria intermedia* (figs. 9–11, No. 9322) and *C. napalensis* (figs. 12–13, No. 8340390). 9: A cross section showing two growth ring boundary and semi-ring porous structure (×40). 10: A more magnified cross section showing pore multiple and vasicentric and confluent wood parenchyma (×100). 11: A tangential section showing big rays and fairly distinctly storied structure (×40). 12: A radial section showing small vessels and storied wood parenchyma (×200). 13: A radial view of a big ray showing upright, square and procumbent cells with crystals (×200).

Plate VII. *Coriaria terminalis* (figs. 14–16, No. 12316) and *C. napalensis* (figs. 17–18, No. 8340390). 14: A cross section showing one growth ring boundary and pore arrangement (×40). 15: A more magnified cross section showing a growth ring boundary and multiple pores with rather scarce wood parenchyma (×100). 16: A tangential section showing big rays and indistinctly storied structure (×40). 17: Alternately and contiguously arranged intervessel pits observed by light microscope (×400). 18: Intervessel pits without any signs of vestured pits observed by scanning electron microscope (about ×750, a black bar in the picture indicates 10 μm).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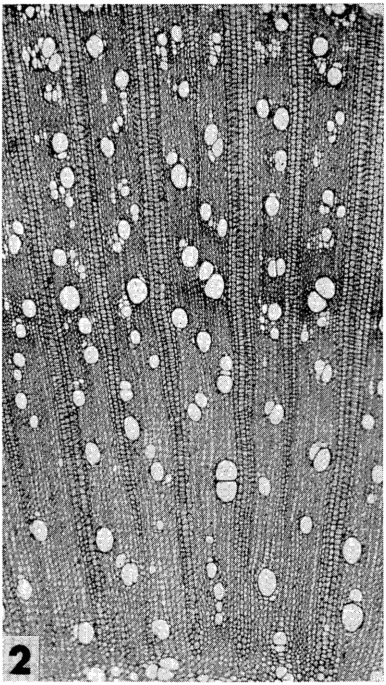
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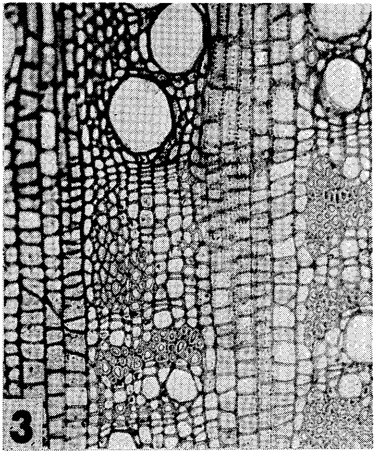
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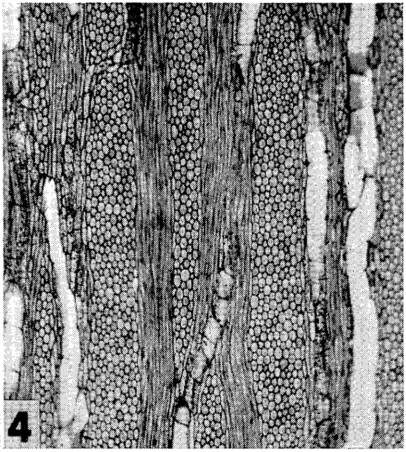
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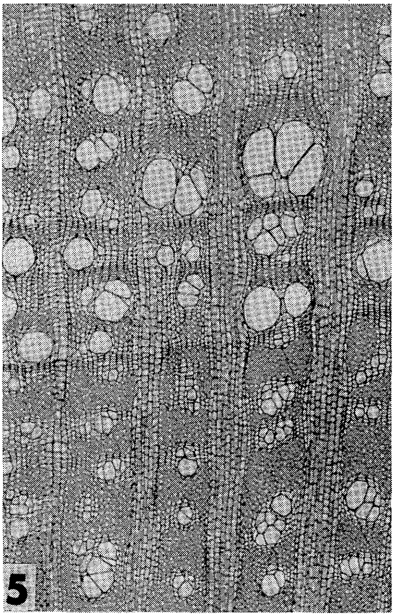
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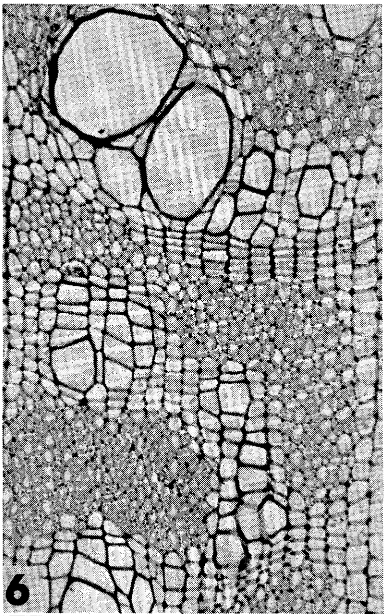
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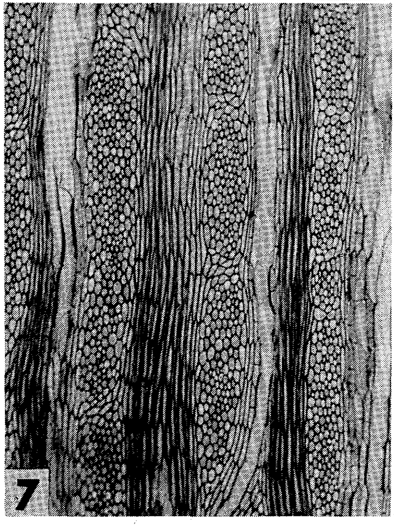
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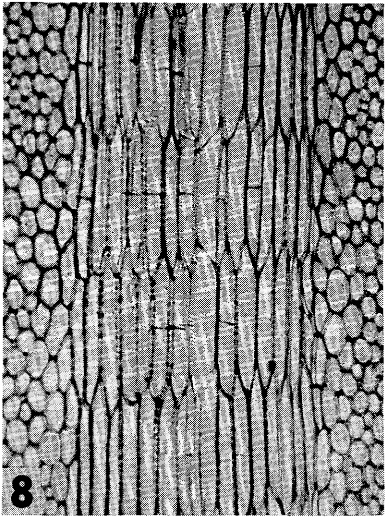
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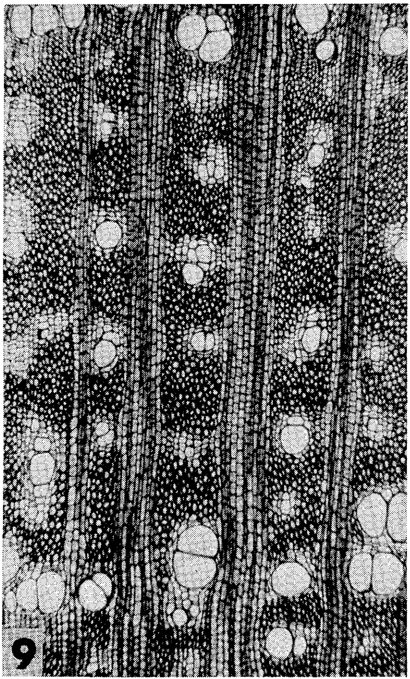
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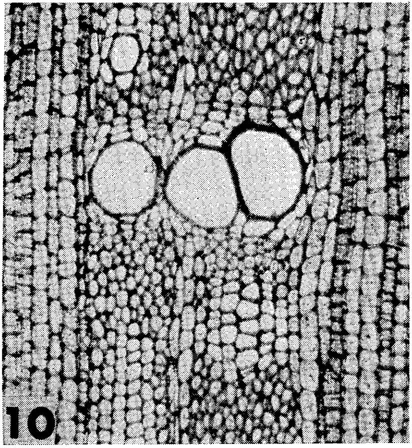
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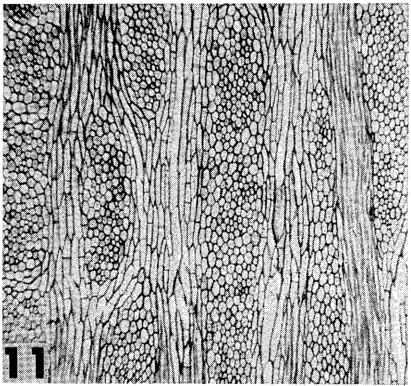
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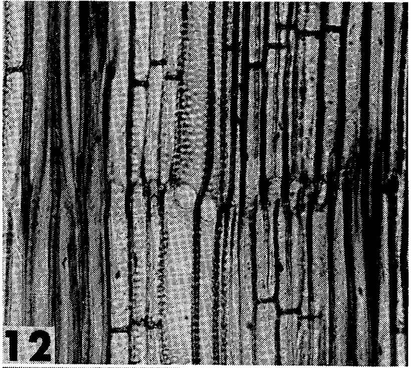
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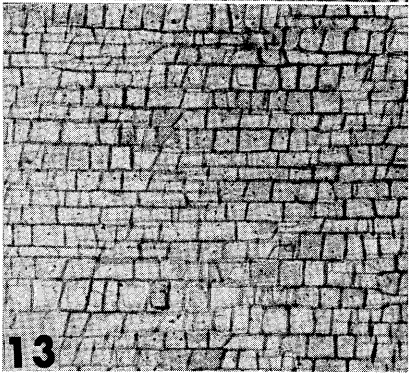
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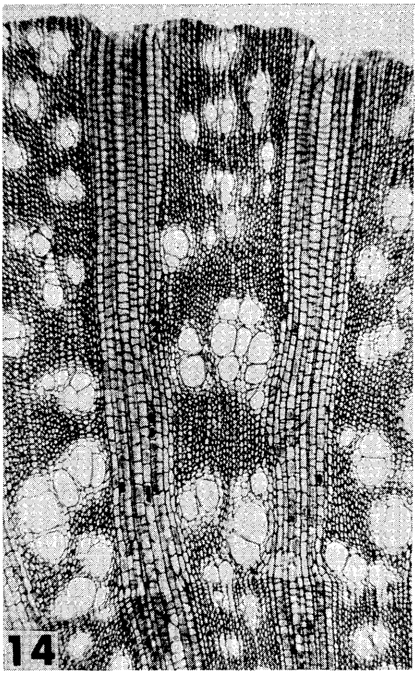
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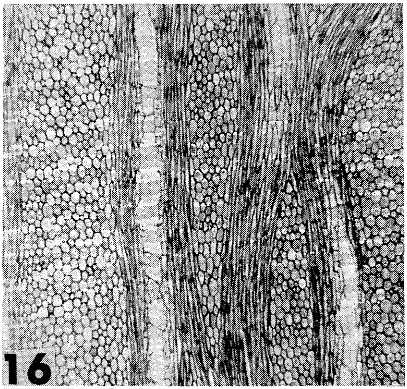
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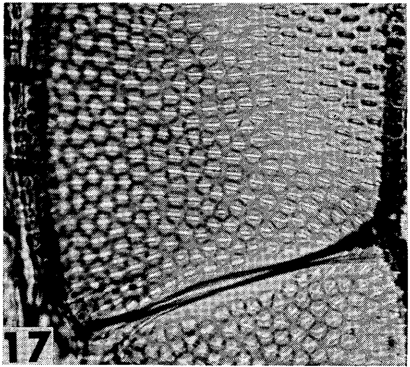
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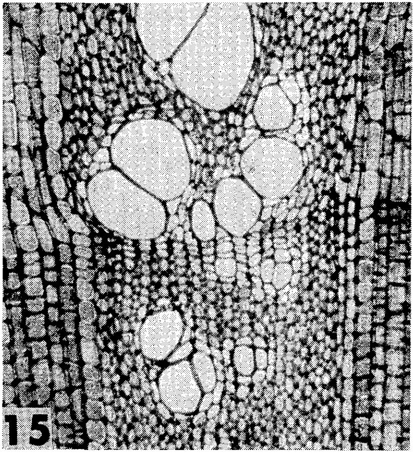
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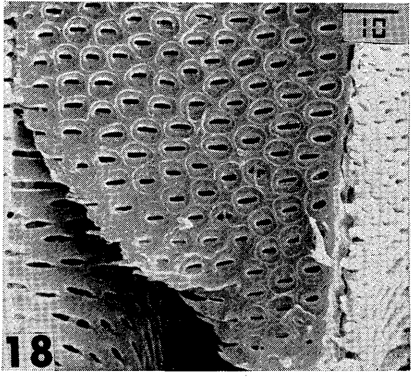

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